MITIGATION OF FERRORESONANCE IN POWER TRANSMISSION NETWORK BY APPLYING UPFC AND STATCOM

JALAL TAVALAEI

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ABSTRACT

Ferroresonance phenomenon occurs in electrical circuits which are consisting of magnetizing cores, such as in the transmission and distribution networks with transformers, electrical machines or reactors. Transformers often operate close to the knee point of the magnetizing curve under normal condition. Therefore any sudden change in voltage or current can change the operating point on the magnetizing curve and saturation may result. This phenomenon is reflected in the change of the equivalent nonlinear reactance of the transformer. Now, if the value of the saturated reactance reaches a value such that it causes resonance with the equivalent capacitance of the network, then an over current or over voltage may occur. Transformers, electrical motors, reactors and generators are examples of equipment having magnetizing cores. Ferroresonance may cause melting of the lamination of the transformer or electrical machine which eventually may lead to the failure of the equipment. This type of fault can create long time interruptions. Possible causes of ferroresonance are switching, faults especially single line to ground or double line to ground, lightning, and Ferranti effect. Although some techniques had been applied to mitigate ferroresonance on CVTs, methods to mitigate ferroresonance on power transformers are almost not studied or reported. This report initially introduces the ferroresonance phenomenon, its definition and circumstances where it occurs. The software used for the simulation is then introduced, whereby the modeling work of the components relevant to the present work is discussed. The simulation work then follows, where suitable circuits for ferroresonance simulation were identified, including those for the mitigation techniques, namely the UPFC and STATCOM. The circuits used to represent the network are introduced and the simulation results are presented and discussed. The UPFC in mode-1 and the STATCOM techniques of mitigation had been shown to successfully mitigate the ferroresonance.

ABSTRAK

Fenomena ferroresonance berlaku dalam litar elektrik yang mengandungi teras pemagnetan, seperti dalam rangkaian penghantaran dan pengagihan yang mempunyai pengubah, mesin elektrik dan reaktor. Pengubah sering beroperasi hampir ke titik lutut lengkung pemagnetan dalam keadaan biasa. Oleh itu, apa-apa perubahan dalam voltan atau arus secara tiba-tiba boleh menukar titik operasi pada lengkung pemagnetan dan ketepuan boleh terhasil. Fenomena ini dapat dilihat dalam perubahan regangan setara tak lelurus pengubah. Jika nilai regangan tepu mencapai satu nilai yang menyebabkan resonan dengan kemuatan setara rangkaian, maka voltan atau arus lampau mungkin berlaku. Pengubah, motor elektrik, reaktor dan penjana adalah contoh peralatan yang mempunyai teras pemagnetan. Ferroresonan boleh mengakibatkan peleburan laminasi pengubah atau mesin elektrik, seterusnya boleh memusnahkannya. Kersoakan ini boleh mewujudkan gangguan kuasa untuk masa yang lama. Antara punca kejadian ferroresonan ialah pensuisan, kerosakan terutamanya talian tunggal ke bumi atau talian berkembar ke bumi, kilat, dan kesan Ferranti. Walaupun beberapa teknik digunakan untuk mengurangkan ferroresonan pada CVTs, kaedah untuk mengurangkan ferroresonan pada pengubah kuasa hampir tidak dikaji atau dilaporkan. Laporan ini pada mulanya memperkenalkan fenomena ferroresonan, definisi dan keadaan di mana ia berlaku. Perisian yang digunakan untuk penyelakuan kemudiannya diperkenalkan, di mana kerja-kerja pemodelan komponen-komponen yang berkaitan dengan kerja-kerja ini dibincangkan. Berikutnya, kerja-kerja simulasi dilaksanakan di mana litar yang sesuai untuk ferroresonan dikenalpasti, termasuk teknik pencegahan menggunakan UPFC dan STATCOM. Litar yang digunakan untuk mewakili rangkaian diperkenalkan dan keputusan simulasi dibentangkan dan dibincangkan. Kaedah pencegahan menggunakan UPFC (mod-1) dan STATCOM didapati mampu mencegah ferroresonan degan baik.

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LIST OF SYMBOLS

C_d	-	Grading Capacitance
C_w	-	Winding Capacitance
C_m	-	Line to line Capacitance
C_g	-	Line to ground Capacitance
C_s	-	Coupling Capacitance
$R_m(v)$	-	Transformer Core Losses
$L_m(\varphi)$	-	Nonlinear Inductance
X_L	-	Impedance of Inductor
X_C	-	Impedance of Capacitor
L_{sat}	-	Non-linear Inductor Saturation
h_C	-	Coercive Magnetic Field
h_m	-	Last Return Point of the Magnetic Field
M_{rev}	-	Reversible Component of Magnetizing
M_{irr}	-	irreversible Component of Magnetizing
M_{an}	-	Anhysteretic Curve
M_s	-	Saturation Magnetizing
H_e	-	External applied Field
α	-	Molecular field parameter

CHAPTER 1

INTRODUCTION

1.1 Project Background

Ferroresonance phenomenon occurs in electrical circuits which are consisting of magnetizing cores, such as in the transmission and distribution network.

Transformers often operate close to the knee point of magnetizing curve under normal condition. Therefore any sudden change in voltage or current can change the operation point on the magnetizing curve and saturation may result.

This phenomenon is reflected in the change of the equivalent nonlinear reactance of the transformer. Now, if the value of the saturated reactance reaches a value such that it causes resonance with the equivalent capacitance of the network, then an over current or over voltage may occur.

Transformers, electrical motor, reactors and generators are examples of equipment having magnetizing cores.

Possible causes of ferroresonance occurrence are:

i. Switching operations
ii. Faults (specially SLG)
iii. Lightning surges
iv. Ferranti effects

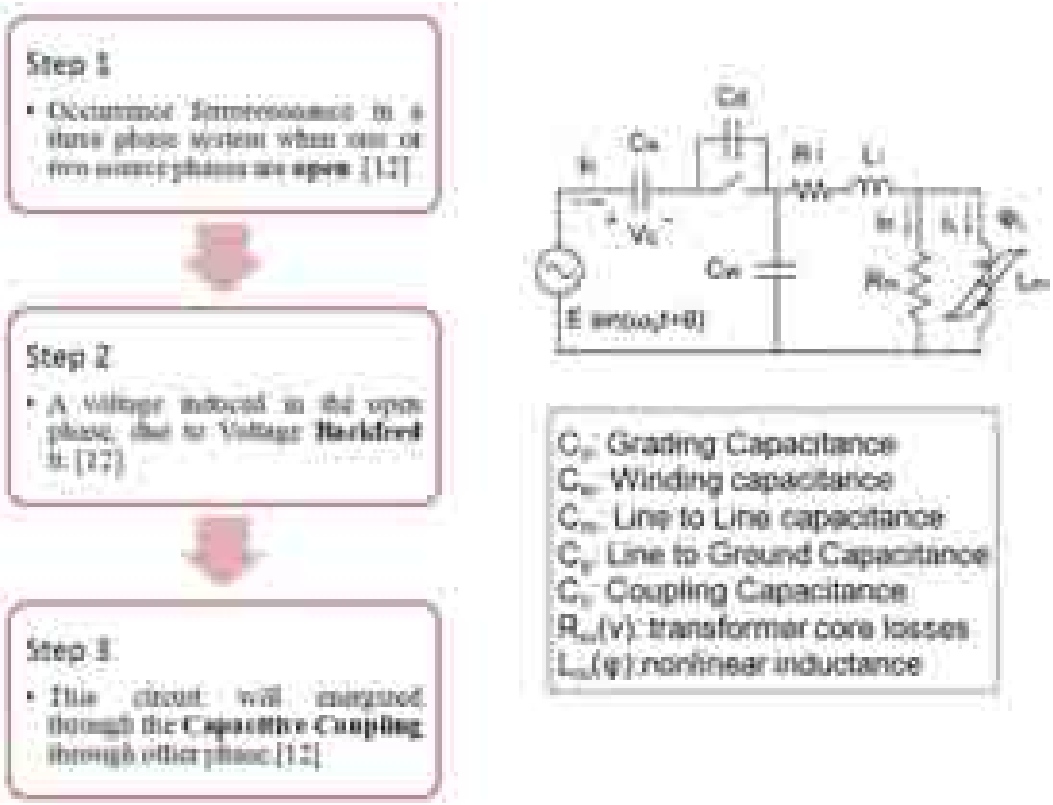

Figure1.1: Steps of formation of ferroresonance and coupling capacitance

1.2 Problem Statement

Although some techniques had been applied to mitigate ferroresonance on capacitive VTs, methods to mitigate ferroresonance on power transformers are almost not studied or reported. This project simulates circuit models of ferroresonance based on two mitigation techniques so as to reduce or prevent damages due to ferroresonance.

1.3 Objectives

- To identify ferroresonance phenomenon and its models
- To model ferroresonance by applying ATP.
- To model and analyze the UPFC and STATCOM effect on mitigation of ferroresonance.

1.4 Scope of Project

The main scope of this project is to model ferroresonance phenomenon at transmission network, due to single line switching. Nonlinear inductor of power transformer resonates with coupling capacitance and cause ferroresonance. Therefore, the current in the opened phase bounce up and highly distorted. Because of the FACTS device connection and its switching time control, the network topology changes. Thus over current and over voltage are therefore damped by the application of the UPFC and STATCOM.

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